# TOTAL SOLAR RADIATION AT NEW ORLEANS, LA.

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[Laboratory of Physiology in the School of Medicine, Tulane University of Louisiana, New Orleans, La., September 1934]

In a previous publication from this laboratory [1] we presented data concerning the intensity and spectral distribution of solar radiation in New Orleans from the beginning of 1928 through the first half of 1932. The material included measurements of total solar radiation (direct and diffuse) on a horizontal plane for seven months in 1931 and for eight months in 1932. Additional values have since been obtained for the rest of 1932 and for 1933 and form the basis of this report.

Continuous records of the total solar radiation (direct and diffuse) were obtained using Kimball and Hobbs' pyrheliometer [2] as modified by the Eppley Laboratory, in conjunction with a Richard recording millivoltmeter. The pyrheliometer was calibrated through the kindness of Dr. Kimball at the United States Weather Bureau, Washington, against a Marvin pyrheliometer which had been compared with the Standard Smithsonian pyrheliometer. The measurements were made from a tower built on the roof of the laboratory building, the instrument being about 100 feet above sea level. This building is situated on the college campus about 4 miles away from the business center at latitude 29°56′ N., and longitude 90°7′19″. The atmosphere is reasonably clear of smoke and dust and the pyrheliometer so situated that it receives practically unobstructed radiation from sun and sky throughout the year.

The accompanying tables give the average hourly, daily total, and annual radiation (direct and diffuse) as received on a horizontal plane during 1932 and 1933 for all days (tables 1 and 2) and on clear days only (tables 1A and 2A)[3]. Since the principal factors which modify the amount of total radiation (direct and diffuse) received on the earth's surface at any one locality are the altitude of the sun and the clearness of the sky, tables 1A and 2A reflect more clearly the gradual changes in solar altitude, the regularity of which is disturbed when values for all days, clear and cloudy, are included (tables 1 and 2). A comparison of the values given in tables 1A and 2A shows that, with the exception of the months of September, October, and December, the average amount of daily total radiation (direct and diffuse) on clear days in 1933 was above that obtained in 1932, the average daily amount for the year being 24.7 gr. cal. per square centimeter greater. These differences are due in large measure to the inclusion of days which were relatively but not absolutely cloudless, since, according to the method of estimation, a "clear" day is one in which clouds cover 0.3 or less of the sky. This introduces some discrepancy in the comparison of the data for 1932 and 1933, since the latter year was sunnier than usual (see below) and the large number of clear days in 1933, 117 as compared to 98 in 1932, included more days which could be characterized as "very clear" or practically cloudless.

An analysis of tables 1 and 2 shows a much larger average daily radiation during May, June, August, and December in 1933 than in 1932. This is directly referable to the amount of sunshine. Thus the average percent of sunshine hours, 61 of the possible in 1932 and 62 in 1933, was slightly above the normal or long-term average of 58 percent. (See table 3.) In April, June, and July 1932 the amount of sunshine was considerably above normal, but December with 24 percent was within 1 percent of the least amount on record for that or any other month.

On the other hand, January and February in 1933 were slightly below normal, while the other months were above, with March, June, September, November, and December, 20 percent or more above normal. June was the sunniest month on record. This all-time high value for sunshine combined with a record minimum precipitation of 0.59 inch and an unusually high number of clear days (16) resulted in a record high amount of total radiation, the average daily total, calculated from the records of all days (table 2), being 42.6 gr. cal. per square centimeter greater than the average daily value for June 1932, as calculated for clear days only (table 1A), and 135.8 gr. cal. per square centimeter greater than the June 1932 average for all days (table 1).

The close correlation between the percentage of sunshine (average percent of possible sunshine hours as obtained from Weather Bureau records), average cloudiness, and total radiation are shown in figures 1 and 2. During July and August of both years there was a characteristic drop in the amount of sunshine and in total radiation due to excessive cloudiness and precipitation. This point will be discussed in greater detail below.

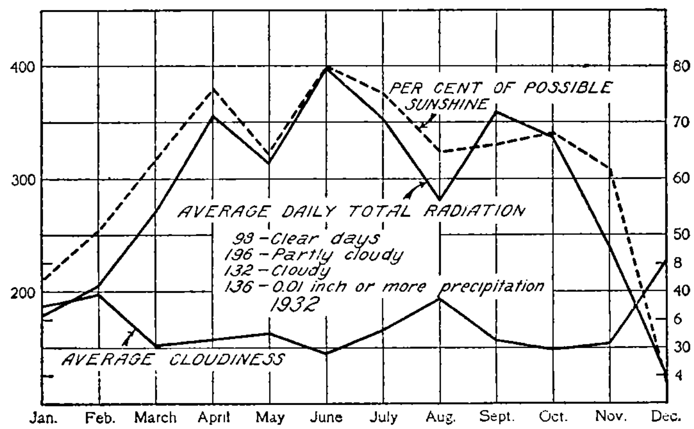


Figure 1.—Average daily total radiation, g. cal. per sq. cm., percent of possible sunshine, and cloudiness in tenths of total sky, for 1932 in New Orleans.

The highest value recorded in 1932 was 1.581 gr. cal. per square centimeter per minute on September 28 at 9:50, at which time cumulus clouds were present near, but not obscuring, the sun, and reflection from them undoubtedly accounts for the high value. The absolute maximum for 1933, 1.725 gr. cal. per square centimeter per minute was reached on July 17 at 12:15 p. m. when cumulus clouds again were a factor. The highest hourly average in 1932 was 1.227 gr. cal. per square centimeter per minute from 11 a. m. to 12 m. on October 6; in 1933, 1.345 gr. cal. per square centimeter per minute between 11 a. m. and 12 m. on June 10. The highest daily total for 1932, 549 gr. cal. per square centimeter, was recorded on October 6, 1932; the maximum in 1933, 651 gr. cal. per square centimeter on June 18.

From data obtained at Washington, D. C., Madison, Wis., Lincoln, Nebr., and Santa Fe, N. Mex., Kimball in

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[1] Laurens, H. and H. S. Mayerson, Intensity and Spectral Distribution of Solar Radiation in New Orleans. Jour. Optical Soc. Amer., 1933, 23, 133.

[2] Kimball, H. H. and H. E. Hobbs, A new Form of Thermoelectric Recording Pyrheliometer. Ibid., 1923, 7, 707.

[3] The number of clear days for each year was obtained from the Annual Meteorological Summary published by the New Orleans Weather Bureau office. With the exception of the readings for total radiation, which were done by us in our laboratory, all other weather data mentioned in this report were obtained from publications of the local Weather Bureau office or from appropriate numbers of Monthly Weather Review.

1919 [4] calculated the intensity of the radiation received on a horizontal surface and the total radiation per day for latitudes 30°, 36°, 42°, and 48° N. Values for total daily radiation on a horizontal surface on cloudless days in New Orleans (and other cities) are given in his table 9A under the heading "Latitude 30° N. (Gulf coast)" and are graphically reproduced in figure 3 of this paper. The

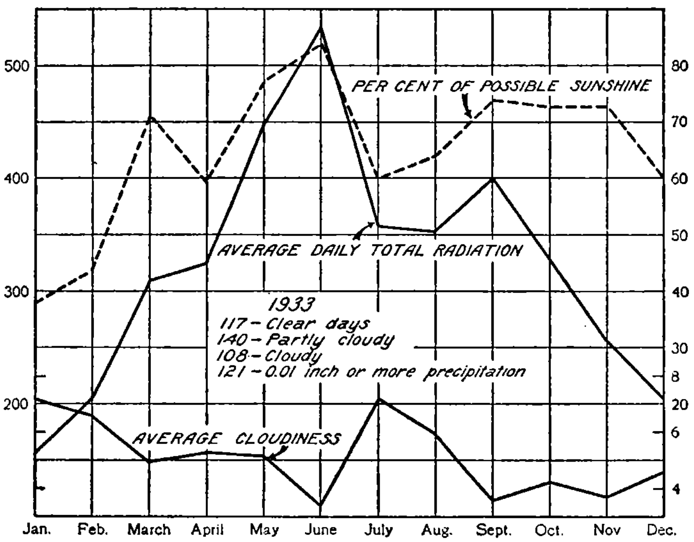


FIGURE 2.—Average daily total radiation, percent of possible sunshine, and cloudiness for 1933 in New Orleans.

curve is decidedly higher than the curves of the observed values for 1932 and 1933 for clear days only. However, if only the very clear or cloudless days are included, there is a gratifying agreement between Kimball's estimated and our observed values.

Table 5 shows values for average daily total radiation (direct and diffuse) for 1932, 1933, and the mean of the averages of the 2 years for New Orleans and 11 other

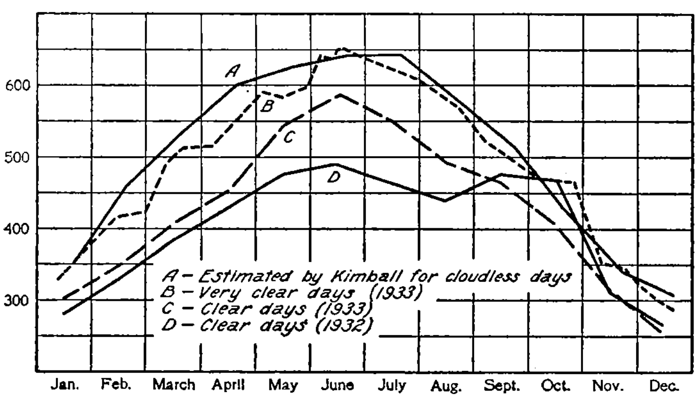


FIGURE 3.—Comparison of estimated (Kimball) and observed average daily total radiation in New Orleans in g. cal. per sq. cm. per min.

cities as calculated from data published in volumes 60 and 61 of the MONTHLY WEATHER REVIEW. Figure 4 shows the respective annual totals in kilogram calories per square centimeter. Table 4 [5] indicates the location of the various stations and the instruments used. Since all of the pyrheliometers (except at Miami) have been calibrated against the Marvin pyrheliometer no. 3, at the Weather Bureau in Washington, the figures are absolutely comparable. The Callendar instrument at Miami probably reads about 3.5 percent lower than the rest.[6]

Of considerable interest are the relatively small amounts of total radiation received during the summer months by stations situated at about latitude 30° as compared with the more northern cities (figs. 5, 6, 7). This is particularly striking in New Orleans, which, as a matter of fact, received less total radiation during July and August of 1932 and 1933 than any of the stations reporting (excepting Gainesville in 1932). This is chiefly due to the extreme distortion of the distribution of rainfall, in the form of thunder showers caused by convectional overturning, which is characteristic of these months. McDonald [7], from an analysis of hourly rainfall in New Orleans for the 30-year period from 1898 through 1927, has pointed out that during June, July, and August there is some rain 10 to 14 percent of the time between noon and 4 p. m. This is in contrast to 4 to 6 percent during April and May, and to 4 to 7 percent during October and November during the same hours. During the winter the rains are well distributed around the hours of the day, but during

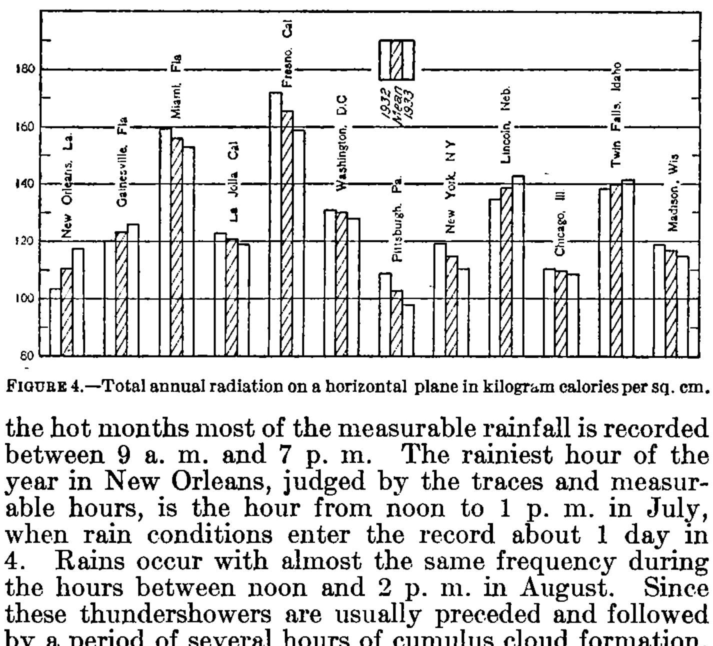


FIGURE 4.—Total annual radiation on a horizontal plane in kilogram calories per sq. cm.

the hot months most of the measurable rainfall is recorded between 9 a. m. and 7 p. m. The rainiest hour of the year in New Orleans, judged by the traces and measurable hours, is the hour from noon to 1 p. m. in July, when rain conditions enter the record about 1 day in 4. Rains occur with almost the same frequency during the hours between noon and 2 p. m. in August. Since these thundershowers are usually preceded and followed by a period of several hours of cumulus cloud formation, the loss in radiation is considerable.

A comparison of the values given in table 5 with those given by Kimball shows clearly that while the total amount of radiation received in different localities can be estimated with reasonable accuracy for cloudless days (as we have shown above for New Orleans), such estimations are of limited value as compared to the averages of all days, clear and cloudy, as obtained by actual measurement at the particular station and reflecting the conditions peculiar to that locality. The measurements in New Orleans are being continued and will be summarized again when sufficient additional data have been accumulated.

[4] Kimball, H. H., Variation in the Total and Luminous Solar Radiation with Geographical Position in the United States. MONTHLY WEATHER REVIEW, 1919, 47, 769.

[5] Rearranged from table given by Kimball, H. H., Solar Radiation Measurements. MONTHLY WEATHER REVIEW, 1932, 60, 26.

[6] Kimball, H. H., Solar Radiation Measurements. MONTHLY WEATHER REVIEW, 1932, 60, 26.

[7] McDonald, W. F., Hourly Frequency and Intensity of Rainfall at New Orleans, La. MONTHLY WEATHER REVIEW, 1929, 57, 1.

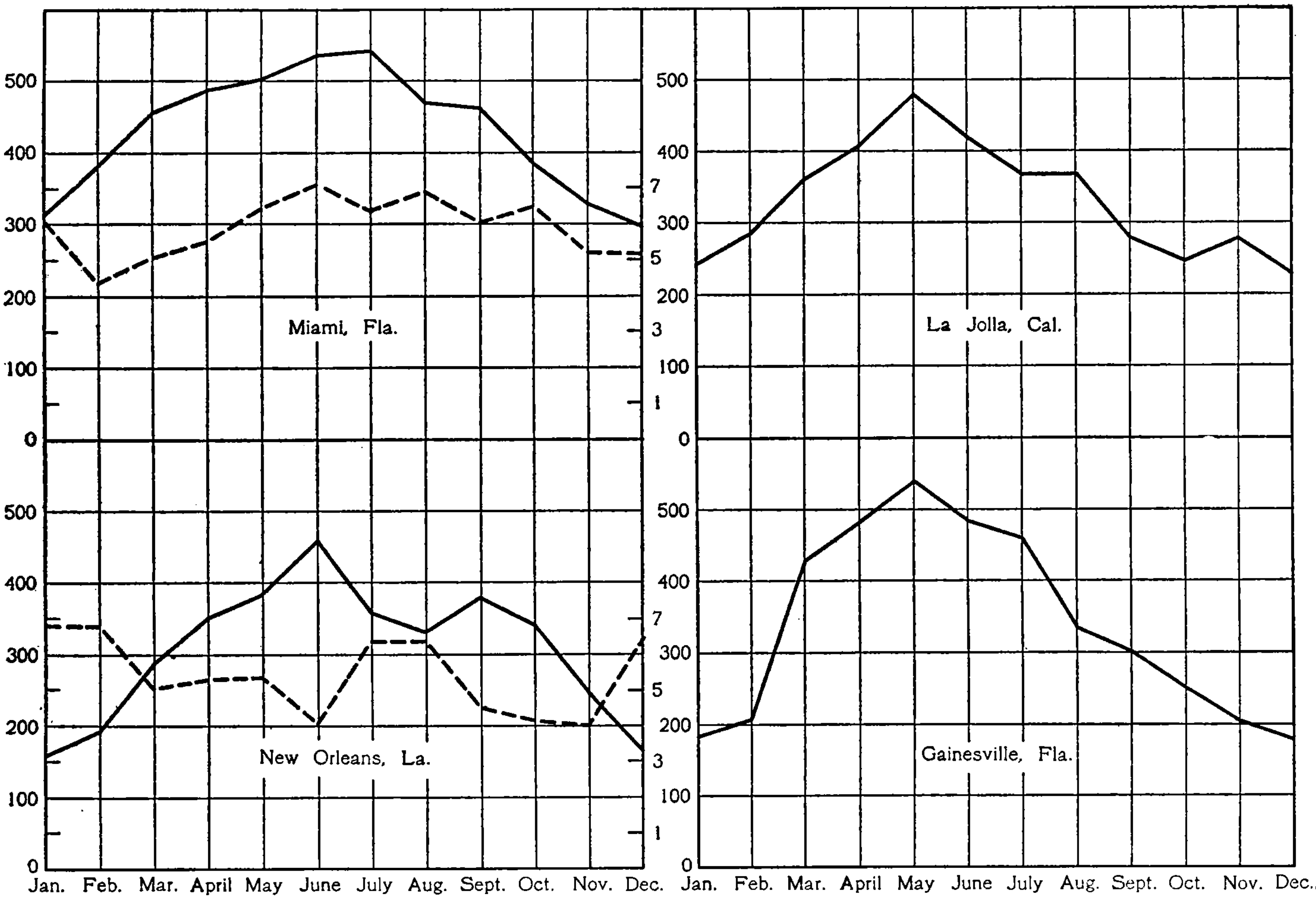


FIGURE 5.—The upper curves represent the means of the values for total daily radiation (direct and diffuse) on a horizontal plane for 1932 and 1933 in g. cal. per sq. cm. The lower curves are similar means of the average cloudiness in tenths of clouded sky. Values for average cloudiness for Gainesville, La Jolla, and Twin Falls were not available.

TABLE 1.—*Average amount of total radiation (direct and diffuse) received on a horizontal surface in gr. cal. per square centimeter per minute. All days, 1932*

| Hour ending (apparent time) | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | Average daily total gr. cal./cm.² |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | ----- | 0.053 | 0.156 | 0.302 | 0.422 | 0.515 | 0.486 | 0.423 | 0.329 | 0.212 | 0.089 | ----- | 179.2 |
| February | 0.010 | .089 | .237 | .422 | .512 | .495 | .472 | .439 | .376 | .247 | .124 | 0.017 | 206.4 |
| March | .034 | .150 | .315 | .472 | .585 | .637 | .650 | .619 | .493 | .348 | .184 | .051 | 272.3 |
| April | .098 | .277 | .460 | .644 | .830 | .767 | .735 | .721 | .605 | .447 | .261 | .097 | 356.5 |
| May | .110 | .215 | .447 | .588 | .656 | .734 | .698 | .564 | .493 | .358 | .249 | .115 | 313.6 |
| June | .262 | .467 | .632 | .706 | .809 | .804 | .787 | .703 | .587 | .447 | .285 | .166 | 399.3 |
| July | .155 | .387 | .589 | .683 | .762 | .738 | .626 | .546 | .491 | .400 | .300 | .207 | 353.0 |
| August | .123 | .293 | .479 | .558 | .621 | .587 | .562 | .499 | .381 | .285 | .201 | .104 | 281.6 |
| September | .150 | .353 | .550 | .659 | .732 | .764 | .782 | .691 | .575 | .393 | .271 | .064 | 359.0 |
| October | .076 | .235 | .453 | .623 | .758 | .776 | .768 | .681 | .560 | .411 | .222 | .064 | 337.6 |
| November | .017 | .114 | .264 | .428 | .533 | .620 | .626 | .585 | .455 | .271 | .101 | .017 | 241.9 |
| December | .005 | .050 | .135 | .231 | .324 | .365 | .336 | .280 | .198 | .114 | .041 | .004 | 125.0 |
| Average for year | .087 | .224 | .393 | .526 | .629 | .650 | .627 | .563 | .462 | .328 | .194 | .076 | 285.5 |

TABLE 2.—*Average amount of total radiation (direct and diffuse) received on a horizontal surface in gr. cal. per square centimeter per minute. All days, 1933*

| Hour ending (apparent time) | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | Average daily total gr. cal./cm.² |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 0.001 | 0.034 | 0.137 | 0.268 | 0.398 | 0.450 | 0.438 | 0.393 | 0.297 | 0.195 | 0.089 | 0.013 | 162.8 |
| February | .005 | .061 | .167 | .301 | .446 | .516 | .476 | .505 | .408 | .302 | .155 | .032 | 202.3 |
| March | .024 | .153 | .323 | .497 | .640 | .715 | .758 | .680 | .575 | .437 | .247 | .080 | 307.7 |
| April | .088 | .220 | .396 | .557 | .657 | .739 | .780 | .724 | .516 | .410 | .253 | .098 | 326.3 |
| May | .160 | .372 | .576 | .780 | .878 | .935 | .985 | .885 | .787 | .594 | .360 | .170 | 448.9 |
| June | .274 | .447 | .707 | .829 | .953 | 1.079 | 1.074 | 1.001 | .848 | .660 | .830 | .217 | 535.1 |
| July | .189 | .378 | .499 | .562 | .692 | .641 | .747 | .772 | .674 | .466 | .344 | .172 | 367.8 |
| August | .143 | .351 | .527 | .627 | .714 | .771 | .728 | .727 | .576 | .458 | .284 | .124 | 361.8 |
| September | .132 | .350 | .573 | .740 | .837 | .886 | .852 | .763 | .684 | .476 | .273 | .100 | 400.0 |
| October | .066 | .226 | .417 | .609 | .749 | .838 | .816 | .745 | .533 | .327 | .146 | .036 | 330.5 |
| November | .019 | .133 | .310 | .473 | .619 | .728 | .712 | .621 | .447 | .228 | .063 | .001 | 261.2 |
| December | .009 | .066 | .200 | .384 | .505 | .531 | .575 | .516 | .393 | .228 | .075 | .003 | 209.1 |
| Average for year | .092 | .233 | .403 | .552 | .674 | .736 | .745 | .694 | .562 | .398 | .260 | .087 | 326.2 |

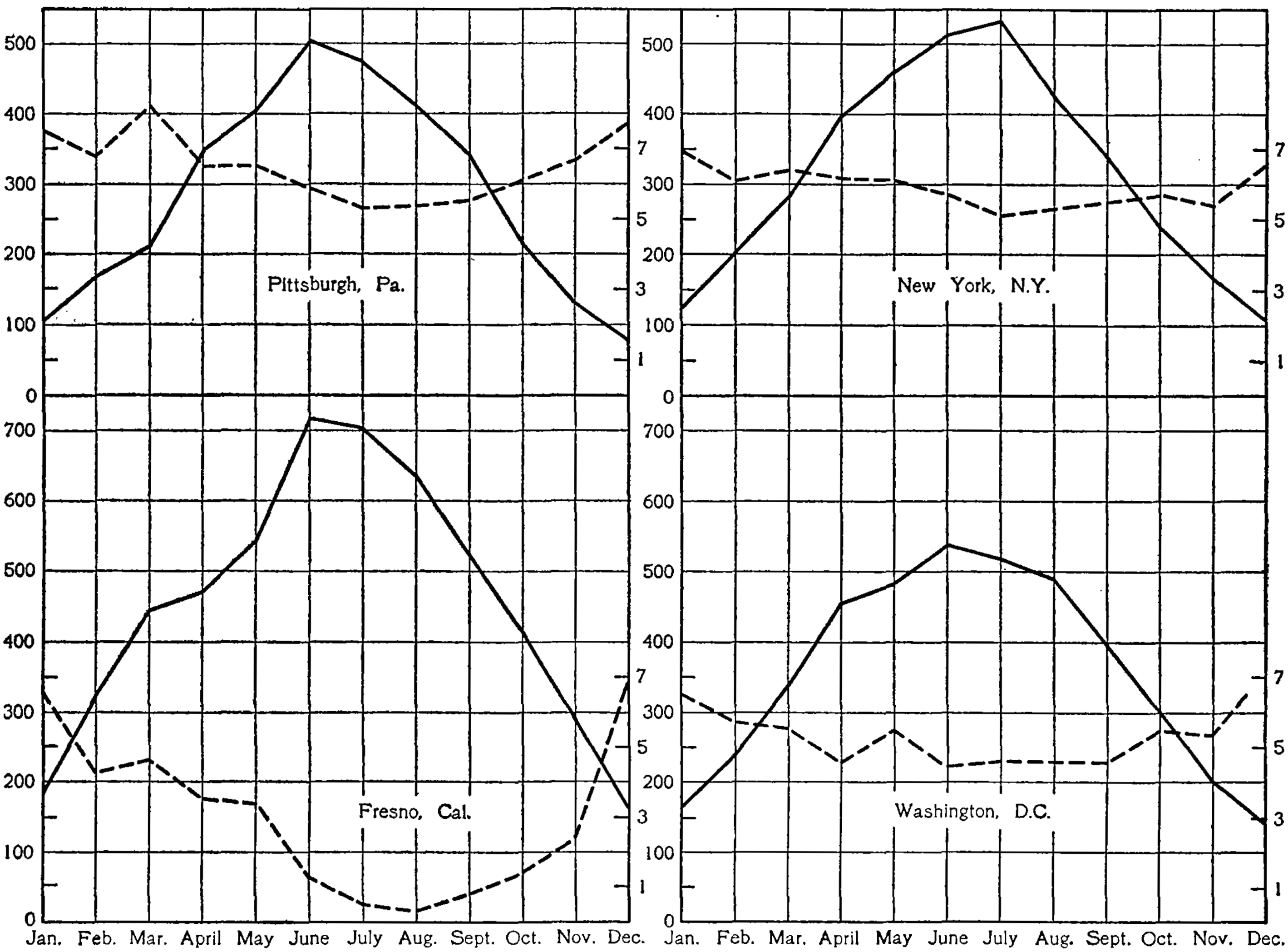


FIGURE 6.—The upper curves represent the means of the values for total daily radiation (direct and diffuse) on a horizontal plane for 1932 and 1933 in g. cal. per sq. cm. The lower curves are similar means of the average cloudiness in tenths of clouded sky. Values for average cloudiness for Gainesville, La Jolla, and Twin Falls were not available.

TABLE 1A.—*Average amount of total radiation (direct and diffuse) received on a horizontal surface in gr. cal. per square centimeter per minute. Clear days only (total=98), 1932*

| Hour ending (apparent time) | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | Average daily total gr. cal./cm.² |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | ----- | 0.082 | 0.259 | 0.484 | 0.704 | 0.805 | 0.836 | 0.768 | 0.591 | 0.376 | 0.150 | ----- | 280.5 |
| February | 0.018 | .155 | .374 | .606 | .746 | .834 | .803 | .720 | .595 | .415 | .217 | .029 | 330.7 |
| March | .044 | .208 | .452 | .687 | .863 | .930 | .905 | .862 | .700 | .480 | .264 | .053 | 386.8 |
| April | .114 | .325 | .574 | .779 | .932 | 1.002 | .947 | .881 | .716 | .502 | .292 | .102 | 430.0 |
| May | .178 | .426 | .645 | .780 | .961 | 1.072 | 1.023 | .889 | .778 | .620 | .396 | .166 | 476.0 |
| June | .269 | .484 | .682 | .790 | .978 | 1.057 | 1.052 | .935 | .804 | .594 | 377 | .186 | 492.5 |
| July | .224 | .440 | .628 | .810 | .958 | 1.057 | 1.031 | .893 | .665 | .553 | .333 | .165 | 465.4 |
| August | .154 | .397 | .625 | .786 | .950 | 1.023 | .980 | .941 | .642 | .468 | .262 | .144 | 442.3 |
| September | .177 | .470 | .689 | .841 | .962 | 1.039 | 1.021 | .968 | .798 | .573 | .307 | .108 | 477.2 |
| October | .105 | .321 | .595 | .843 | 1.013 | 1.091 | 1.071 | .968 | .796 | .604 | .340 | .095 | 470.5 |
| November | .016 | .149 | .374 | .590 | .737 | .816 | .809 | .709 | 538 | .320 | .124 | .019 | 312.1 |
| December | .013 | .132 | .341 | .549 | .704 | .764 | .745 | .596 | .401 | .204 | .050 | .000 | 269.9 |
| Average for year | .109 | .299 | .520 | .712 | .876 | .958 | .910 | .844 | .669 | .476 | .260 | .089 | 403.0 |

TABLE 2A.—*Average amount of total radiation (direct and diffuse) received on a horizontal surface in gr. cal. per square centimeter per minute. Clear days only (total=117), 1933*

| Hour ending (apparent time) | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | Average daily total gr. cal./cm.² |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 0.004 | 0.067 | 0.268 | 0.499 | 0.716 | 0.840 | 0.833 | 0.719 | 0.559 | 0.374 | 0.146 | 0.016 | 302.5 |
| February | .003 | .073 | .259 | .538 | .759 | .895 | .921 | .842 | .711 | .503 | .248 | .057 | 348.5 |
| March | .025 | .172 | .422 | .635 | .855 | .982 | .995 | .908 | .763 | .572 | .313 | .110 | 405.1 |
| April | .126 | .353 | .586 | .807 | .965 | 1.055 | 1.041 | .939 | .765 | .532 | .289 | .086 | 452.6 |
| May | .202 | .484 | .747 | .953 | 1.120 | .995 | 1.224 | 1.139 | .907 | .663 | .448 | .211 | 545.6 |
| June | .285 | .531 | .809 | .950 | 1.112 | 1.244 | 1.193 | 1.128 | .964 | .777 | .531 | .250 | 586.4 |
| July | .206 | .457 | .685 | .745 | 1.075 | 1.186 | 1.212 | 1.110 | 1.041 | .784 | .456 | .229 | 551.2 |
| August | .136 | .383 | .649 | .813 | .972 | 1.016 | 1.040 | 1.052 | .968 | .719 | .343 | .117 | 492.5 |
| September | .143 | .364 | .608 | .812 | .959 | 1.042 | 1.046 | .945 | .830 | .587 | .303 | .112 | 465.5 |
| October | .090 | .289 | .504 | .799 | .956 | 1.017 | .998 | .893 | .647 | .376 | .170 | .056 | 407.3 |
| November | .024 | .153 | .362 | .590 | .770 | .867 | .864 | .742 | .551 | .269 | .076 | .000 | 316.1 |
| December | .015 | .091 | .265 | .482 | .650 | .680 | .726 | .623 | .472 | .234 | .072 | .001 | 258.7 |
| Average for year | .105 | .276 | .514 | .719 | .908 | .985 | 1.008 | .920 | .765 | .533 | .283 | .103 | 427.7 |

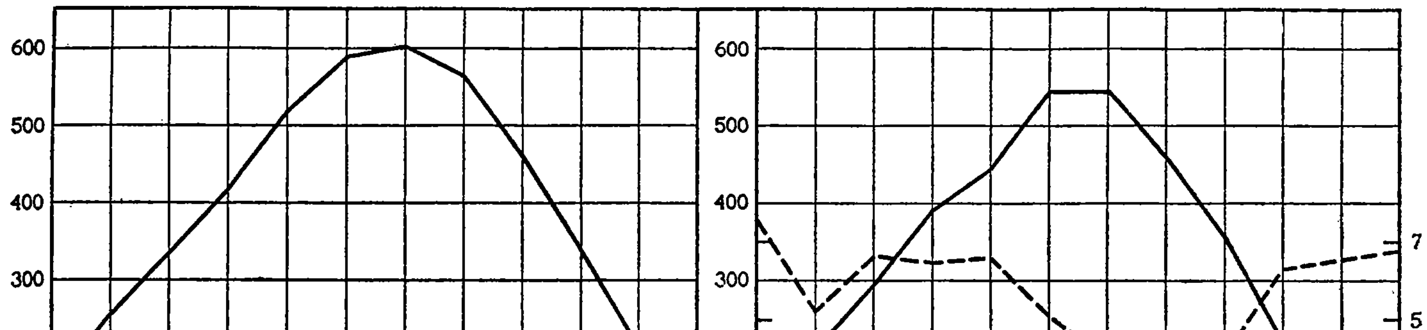


Figure 7.—The upper curves represent the means of the values for total daily radiation (direct and diffuse) on a horizontal plane for 1932 and 1933 in g. cal. per sq. cm. The lower curves are similar means of the average cloudiness in tenths of clouded sky. Values for average cloudiness for Gainesville, La Jolla, and Twin Falls were not available.

Table 3.—*Average and extreme values for New Orleans*

[From Annual Meteorological Summary, Weather Bureau, 1933]

| Month | Precipitation average (total inches) | Sunshine: Total | Sunshine: per cent of hours possible | Sunshine: Highest per cent of | Sunshine: Lowest per cent of | Average number of days: Clear | Partly cloudy | Cloudy | Rain 0.01 inch or more | Thunderstorms |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of years | 63 | 43 | 43 | 43 | 43 | 63 | 63 | 63 | 63 | 34 |
| January | 4.57 | 159 | 49 | 77 | 28 | 9 | 10 | 12 | 10 | 2 |
| February | 4.39 | 159 | 50 | 72 | 23 | 9 | 9 | 10 | 9 | 3 |
| March | 5.09 | 212 | 57 | 92 | 26 | 11 | 10 | 10 | 9 | 4 |
| April | 5.27 | 240 | 63 | 86 | 26 | 11 | 11 | 8 | 7 | 4 |
| May | 4.87 | 283 | 67 | 85 | 44 | 12 | 13 | 6 | 9 | 7 |
| June | 5.73 | 266 | 63 | 84 | 37 | 9 | 15 | 6 | 13 | 11 |
| July | 6.54 | 244 | 57 | 81 | 31 | 7 | 16 | 8 | 15 | 15 |
| August | 5.91 | 234 | 57 | 86 | 24 | 7 | 17 | 7 | 14 | 15 |
| September | 5.23 | 235 | 64 | 80 | 32 | 12 | 12 | 6 | 10 | 8 |
| October | 3.48 | 237 | 67 | 87 | 39 | 16 | 9 | 6 | 7 | 2 |
| November | 3.57 | 185 | 59 | 81 | 33 | 13 | 9 | 8 | 7 | 1 |
| December | 4.69 | 142 | 45 | 68 | 23 | 9 | 9 | 13 | 11 | 2 |
| Year | 59.34 | 2,594 | 58 | 71 | 45 | 125 | 140 | 100 | 121 | 74 |

Table 4.—*Location of stations and instruments used*

| Stations | Instruments | Registers | Latitude | Longitude | Altitude |
|---|---|---|---|---|---|
| | | | ° ′ | ° ′ | Feet |
| New Orleans, La | Eppley | Richard | 29 56 N. | 90 07 W. | 100 |
| Gainesville, Fla | Moll | do | 29 39 N. | 84 21 W. | 233 |
| Miami, Fla | Callendar | Callendar | 25 41 N. | 80 12 W. | |
| La Jolla, Calif | Weather Bureau | Engelhard | 32 50 N. | 117 15 W. | 85 |
| Fresno, Calif | Eppley | do | 36 43 N. | 119 49 W. | 30 |
| Washington, D. C | Marvin | | 38 56 N. | 77 05 W. | 397 |
| | Eppley | Engelhard | | | 414 |
| Pittsburgh, Pa | do | do | 40 32 N. | 80 02 W. | 1,114 |
| New York, N. Y | do | do | 40 46 N. | 73 58 W. | 156 |
| Lincoln, Nebr | Marvin | | 40 50 N. | 96 41 W. | 1,225 |
| | Callendar | Callendar | | | 1,250 |
| Chicago, Ill | Eppley | Engelhard | 41 47 N. | 87 35 W. | 688 |
| Twin Falls, Idaho | do | do | 42 29 N. | 114 25 W. | 4,300 |
| Madison, Wis | Marvin | | 43 05 N. | 89 23 W. | 974 |
| | Callendar | Callendar | | | 1,009 |

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TABLE 5.—*Average daily total radiation (direct and diffuse) received on a horizontal plane in gr. cal. per square centimeter*

| | New Orleans, La. (lat. 29°56′ N; alt. 100 feet) | | | Gainesville, Fla. (lat. 29°39′ N; alt. 233 feet) | | | Miami, Fla. (lat. 25°41′ N) | | | La Jolla, Calif. (lat. 32°50′ N; alt. 85 feet) | | | Fresno, Calif. (lat. 36°43′ N; alt. 330 feet) | | | Washington, D. C. (lat. 38°56′ N; alt. 414 feet) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1932 | 1933 | Average | 1932 | 1933 | Average | 1932 | 1933 | Average | 1932 | 1933 | Average | 1932 | 1933 | Average | 1932 | 1933 | Average |
| Jan. 1-28 | 157 | 171 | 164 | 242 | 130 | 186 | 344 | 275 | 310 | 278 | 214 | 246 | 210 | 148 | 179 | 143 | 179 | 161 |
| Jan. 29-Feb. 25 | 194 | 199 | 197 | 233 | 178 | 205 | 409 | 356 | 383 | 291 | 287 | 239 | 322 | 327 | 325 | 212 | 268 | 240 |
| Feb. 26-Mar. 31, 1932<br>Feb. 26-Apr. 1, 1933 | 276 | 299 | 288 | 432 | 431 | 432 | 472 | 438 | 455 | 384 | 346 | 365 | 441 | 455 | 447 | 332 | 347 | 340 |
| Apr. 1-28, 1932<br>Apr. 2-29, 1933 | 370 | 338 | 354 | 545 | 414 | 435 | 534 | 439 | 487 | 481 | 341 | 411 | 558 | 389 | 474 | 473 | 445 | 459 |
| Apr. 29-June 2, 1932<br>Apr. 30-June 3, 1933 | 315 | 456 | 386 | 546 | 539 | 543 | 492 | 509 | 501 | 557 | 412 | 481 | 653 | 444 | 549 | 512 | 459 | 486 |
| June 3-July 1, 1932<br>June 4-July 1, 1933 | 404 | 511 | 458 | 507 | 465 | 486 | 526 | 539 | 533 | 442 | 397 | 420 | 729 | 714 | 722 | 489 | 582 | 536 |
| July 2-29 | 359 | 349 | 354 | 536 | 385 | 461 | 584 | 498 | 541 | 408 | 329 | 369 | 714 | 706 | 710 | 528 | 517 | 523 |
| July 30-Sept. 2 | 288 | 373 | 331 | 262 | 404 | 333 | 465 | 475 | 470 | 332 | 411 | 372 | 645 | 635 | 640 | 540 | 445 | 493 |
| Sept. 3-30 | 347 | 408 | 378 | 222 | 381 | 302 | 436 | 494 | 465 | 232 | 324 | 278 | 498 | 556 | 527 | 441 | 358 | 400 |
| Oct. 1-28 | 346 | 348 | 347 | 204 | 302 | 253 | 397 | 377 | 387 | 220 | 277 | 249 | 421 | 413 | 417 | 277 | 319 | 298 |
| Oct. 29-Dec. 2 | 246 | 254 | 250 | 132 | 275 | 203 | 314 | 339 | 327 | 238 | 320 | 279 | 290 | 300 | 295 | 227 | 185 | 206 |
| Dec. 3-31 | 116 | 213 | 165 | 110 | 247 | 178 | 275 | 311 | 298 | 198 | 260 | 229 | 168 | 153 | 161 | 147 | 134 | 141 |
| Average | 284 | 322 | 303 | 331 | 346 | 339 | 437 | 421 | 429 | 339 | 326 | 333 | 471 | 437 | 454 | 360 | 353 | 357 |
| Total (average times 365) | 103,660 | 117,530 | 110,595 | 120,815 | 126,290 | 123,552 | 159,505 | 153,665 | 156,585 | 123,735 | 118,990 | 121,363 | 171,915 | 159,505 | 165,710 | 131,400 | 128,845 | 130,305 |

| | Pittsburgh, Pa. (lat. 40°32′ N.; alt. 1,114 feet) | | | New York, N. Y. (lat. 40°46′ N.; alt. 156 feet) | | | Lincoln, Nebr. (lat. 40°50′ N.; alt. 1,250 feet) | | | Chicago, Ill. (lat. 41°47′N.; alt. 688 feet) | | | Twin Falls, Idaho (lat. 42°29′ N.; alt. 4,300 feet) | | | Madison, Wis. (lat. 43°05′ N.; alt. 1,009 feet) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1932 | 1933 | Average | 1932 | 1933 | Average | 1932 | 1933 | Average | 1932 | 1933 | Average | 1932 | 1933 | Average | 1932 | 1933 | Average |
| Jan. 1-28 | 94 | 113 | 104 | 96 | 145 | 121 | 177 | 201 | 189 | 85 | 119 | 102 | 159 | 160 | 160 | 100 | 131 | 116 |
| Jan. 29-Feb. 25 | 161 | 180 | 171 | 191 | 211 | 201 | 257 | 315 | 286 | 167 | 203 | 185 | 261 | 263 | 262 | 209 | 227 | 218 |
| Feb. 26-Mar. 31, 1932<br>Feb. 26-Apr. 1, 1933 | 235 | 201 | 213 | 291 | 269 | 280 | 375 | 364 | 370 | 236 | 221 | 229 | 311 | 369 | 340 | 326 | 264 | 295 |
| Apr. 1-28, 1932<br>Apr. 2-29, 1933 | 360 | 343 | 352 | 421 | 365 | 393 | 390 | 460 | 425 | 393 | 359 | 378 | 436 | 385 | 417 | 430 | 354 | 392 |
| Apr. 29-June 2, 1932<br>Apr. 30-June 3, 1933 | 470 | 337 | 404 | 507 | 412 | 460 | 529 | 500 | 515 | 455 | 403 | 429 | 513 | 536 | 525 | 466 | 423 | 445 |
| June 3-July 1, 1932<br>June 4-July 1, 1933 | 500 | 502 | 501 | 490 | 545 | 518 | 541 | 637 | 589 | 518 | 526 | 522 | 596 | 582 | 589 | 532 | 563 | 548 |
| July 2-July 29 | 509 | 458 | 484 | 567 | 463 | 535 | 580 | 599 | 590 | 549 | 556 | 553 | 597 | 605 | 601 | 570 | 522 | 546 |
| July 30-Sept. 2 | 449 | 390 | 420 | 472 | 382 | 427 | 455 | 443 | 449 | 433 | 457 | 440 | 572 | 564 | 568 | 432 | 489 | 461 |
| Sept. 3-30 | 377 | 274 | 346 | 380 | 309 | 345 | 429 | 416 | 424 | 378 | 295 | 337 | 461 | 462 | 462 | 397 | 319 | 358 |
| Oct. 1-28 | 218 | 213 | 216 | 211 | 269 | 210 | 304 | 363 | 334 | 211 | 239 | 225 | 310 | 364 | 337 | 197 | 250 | 224 |
| Oct. 29-Dec. 2 | 132 | 124 | 128 | 175 | 160 | 168 | 215 | 228 | 222 | 113 | 146 | 130 | 181 | 232 | 207 | 132 | 150 | 141 |
| Dec. 3-31 | 79 | 80 | 80 | 119 | 92 | 106 | 187 | 175 | 181 | 110 | 76 | 93 | 163 | 143 | 153 | 119 | 99 | 109 |
| Average | 299 | 268 | 284 | 328 | 302 | 315 | 370 | 392 | 381 | 304 | 300 | 302 | 380 | 389 | 385 | 327 | 316 | 322 |
| Total (average times 365) | 109,135 | 97,820 | 103,478 | 119,720 | 110,230 | 114,975 | 135,050 | 143,080 | 139,065 | 110,960 | 109,500 | 110,230 | 138,700 | 141,985 | 140,340 | 119,350 | 115,340 | 117,345 |

# THE CRITICAL PERIOD OF CORN IN NORTHEASTERN KANSAS

By A. D. ROBB

[Weather Bureau office, Topeka, Kans., July 1934]

This paper is an endeavor to correlate rainfall and the yield of corn in northeastern Kansas, to determine when rain is of the most value and what effect it has on the crop in this section.

The 11 counties, Marshal, Riley, Nemaha, Jackson, Pottawatomie, Brown, Doniphan, Atchison, Jefferson, Leavenworth, and Wyandotte comprise the area for this study. They are the chief corn-producing counties of the State. Statistics of crop yields and precipitation data used are both official, one being obtained from the Bureau of Agricultural Economics and the other compiled by the Weather Bureau. The period used was the 33 years, 1901 to 1933, inclusive.

The method used is familiar and there is no need to explain it here, except to reiterate the fact that the nearer the correlation coefficient, $r$, approaches 1 the closer the relation, and the nearer it approaches 0 the less the relation. Some writers believe that the influence of one factor upon another is well established if the correlation coefficient is 3 times the probable error, while others think that it should be 6 times that value. It is better to assume that there may be some connection if the correlation coefficient is 3 times the probable error and that the relation is established beyond question if it is more than 6 times that error. Correlation coefficient tables have been worked out according to this method for the 33-year period in northeastern Kansas, first for calendar months and then for other periods.

TABLE 1.—*Relation between rainfall and corn yields in northeastern Kansas by months, 1901–33*

| Period of rainfall | Correlation coefficient, $r$ | Period of rainfall | Correlation coefficient, $r$ |
|---|---|---|---|
| May | +0.01 | September | +0.05 |
| June | +0.30 | June and July | +0.61 |
| July | +0.58 | July and August | +0.80 |
| August | +0.51 | June, July, and August | +0.74 |